

Megachannel Extraterrestrial Assay Candidates: No Transmissions from Intrinsically Steady Sources

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ABSTRACT

This paper reports new, more sensitive observations of nine of the eleven extrastatistical signals in the Megachannel Extraterrestrial Assay (META). These extrastatistical signals had all of the expected characteristics of a transmission from an extraterrestrial transmitter, except that they did not repeat. Cordes, Lazio, & Sagan showed that this lack of repeatability could be explained by the high detection thresholds used in the re-observations of these candidates combined with interstellar scintillation of intrinsically steady sources. We use the CLS97 methodology, correcting an error in the original presentation, and our new observations to rule out this scintillation hypothesis at a confidence level of at least 97.8% (for the case of an intrinsically weak source) to a level in excess of 99% (if the source strengths are comparable to that favored by CLS97). We also demonstrate that gravitational microlensing cannot account for the initial detection of these candidate signals nor is gravitational lensing likely to play a role in future SETI programs. We conclude that the META candidates do not reflect a large population of powerful, strong beacons.

Subject headings: extraterrestrial intelligence — gravitational lensing — scattering

1. Introduction

Various searches for extraterrestrial intelligence (SETI) have found signals having all of the expected characteristics of hypothesized ET transmitters, except one. The candidate signals are

narrowband, often are in or near a “magic frequency” in a “special” reference frame (e.g., the Galactic barycenter), do not match the characteristics of known, interfering signals of terrestrial or solar system origin, and yet, do not repeat when follow-up observations of the relevant sky positions are performed. Among the relevant programs are the Megachannel Extraterrestrial Assay (META, Horowitz & Sagan 1993, hereinafter HS93), which found several dozen such signals at 1420 and 2840 MHz, and the old Ohio State SETI program (Dixon 1985), which found the “WOW!” signal at 1420 MHz. (The SERENDIP programs [Bowyer et al. 1995] define candidate signals as those that have been detected multiple times at the same sky position, but only modest efforts have been made to analyze these candidates further and it is not clear yet if these candidates can be eliminated as intrinsically steady sources in the way that the META candidates are below.)

By contrast with such an idealized type of signal, it is easy to imagine that received signals might depart significantly from this idealization, particularly with regard to duration and amplitude stability. Cordes, Lazio, & Sagan (1997, hereinafter CLS97) listed (possibly incompletely) reasons for a received signal to appear intermittent:

1. Noise in the receiver electronics, e.g., thermal noise, cosmic ray induced events, and hardware failures;
2. Radio frequency interference (RFI) whose origin is terrestrial, from Earth orbit, or from interplanetary spacecraft;
3. Natural, extrinsic modulation of a (unknown) class of narrowband astrophysical sources such as that caused by interstellar (radio) scintillation (ISS) or gravitational lensing;
4. Natural, extrinsic modulation of ETI sources; and
5. Intrinsic intermittency at the source of an ETI signal due to natural causes, such as planetary rotation or the nature of the transmission (e.g., planetary radar) or, for deliberate reasons, to frustrate detection and decryption by non-target civilizations.

They then proceeded to analyze the impact of Cause 4 upon SETI surveys, with particular emphasis on ISS, motivated by the following considerations. First, it seems to be the simplest mechanism for producing transient signals from otherwise intrinsically steady signals that is amenable to testing. Second, observations of pulsars and active galactic nuclei have demonstrated that ISS is important at centimeter wavelengths (Rickett 1990) that are commonly used in searches for ETI (Oliver 1973).

CLS97 were able to show that ISS *by itself* is sufficient to explain the lack of confirmation of any ETI candidate signals in surveys conducted to date. They also predicted the sensitivities required to rule out the scintillation modulation hypothesis.

This paper reports new observations of nine of the eleven META candidates, observations with the requisite sensitivity to allow ISS to be ruled out. In §2 we summarize the extrastatistical

candidates from the META and what the ISS hypothesis requires about their signal strengths, in §3 we describe the additional observations we have conducted. We demonstrate that ISS cannot be responsible for modulating an intrinsically steady signal to produce the META candidates in §4 and that gravitational microlensing cannot do the same in §5. We summarize our conclusions in §6.

2. The Extrastatistical META Candidates

In this section we summarize briefly the relevant properties of the META extrastatistical signals. For full details of META and the various signals detected, see HS93.

META conducted five surveys of the northern sky, three at the frequency 1420 MHz and two at 2840 MHz, between 1986 and 1991. At each sky position observed, two polarizations were searched in each of three reference frames—the Local Standard of Rest, the Galactic barycenter, and the cosmic microwave background. The vast majority of the signals analyzed were consistent with an exponential distribution as expected for noise from a Fourier transform spectrometer.

Of the roughly 6×10^{13} observations analyzed during the five-year META, only eleven could not be explained as due to either noise or processor failure, e.g., due to cosmic-ray hits on the electronics. It was these eleven extrastatistical detections, four at 1420 MHz and seven at 2840 MHz, that HS93 identified as being candidates for detections of ETI transmitters.

All eleven candidates were narrowband, with the broadest being only four spectrometer channels wide; each channel was 0.05 Hz. Some candidates were unresolved. During the survey, the processing software could halt the survey observations and acquire reobservations on “interesting” signals within 40 s of detection. (The eleven candidates were identified only after the conclusion of META so far more than just the eleven candidates were reobserved in this manner.) In no case was a candidate reobserved during the immediate reobservations. Furthermore, various followup observations were attempted over a five-year period, and no candidate was detected again. (Intense scrutiny of the WOW sky position has also failed to redetect a signal, Gray 1995; Gray & Marvel 2001)

With the exception of the lack of reobservation, the candidates had all of the characteristics expected of ETI transmitters: Narrowband signals in a celestial reference frame. The eleven extrastatistical candidates also all had low Galactic latitudes, consistent with that expected for a Galactic population. HS93 also considered the possibility that these candidates represent signals from a previously unrecognized class of natural sources. Throughout the rest of this paper we shall discuss the candidates as if they are ETI transmitters, but our comments will be equally applicable if they represent a natural class of sources.

3. Observations

We observed nine of the eleven META candidates during the interval 1997–1998 as part of Project Phoenix (Cullers 2000). Table 1 summarizes the observing log. We also report the candidate positions in a common and conventional equinox (J2000).

For a complete discussion of the observational methodology of Project Phoenix, see Cullers (2000). We shall summarize only the relevant details. Coordinated observations were conducted with the 43 m (140 ft) NRAO telescope at Green Bank, WV, and a 30 m telescope in Woodbury, GA. Initial observations were conducted with the NRAO telescope employing a filter to excise terrestrial interference. The detection of a possible signal exceeding a specified threshold (see below) was then transmitted to the telescope in Woodbury. Employing a matched filter and a lower threshold, the telescope at Woodbury re-observed the sky position. A signal had to be detected at both telescopes in order to be considered a genuine celestial signal.

The original META observations used a telescope with a $0^\circ.5$ beamwidth (FWHM) at a frequency of 1420 MHz. In order to cover this area fully with our smaller beam, $0^\circ.3$ at 1420 MHz, a grid of positions centered on the nominal position of the META candidate was observed. The grid included the nominal position of the candidate and pointings separated by $0^\circ.3$ north, east, south, and west of the nominal position.

At each pointing position an integration time of 300 s was used. The bandwidth of the individual spectral channels was 0.68 Hz (vs. 0.05 Hz in META). The equivalent (1σ) sensitivity was $1.4 \times 10^{-27} \text{ W m}^{-2}$, and the initial detection threshold for the NRAO telescope was 7σ . For comparison the typical META sensitivity (1σ) was $5.7 \times 10^{-25} \text{ W m}^{-2}$, and the threshold for the extrastatistical candidates described in §2 was 31.7σ .

CLS97 normalized intensities to the mean noise level $\langle N \rangle$ in the META spectrometer. We shall continue to do so as well. The choice of whether to use the META or Project Phoenix noise level is arbitrary, but because the intrinsic signal strength of the (putative) transmitters is also normalized by $\langle N \rangle$, we must be consistent. Denoting the normalized intensities by η (as CLS97 did), the various observational thresholds described above become $\eta = I/\langle N \rangle = 31.7$ for META, $\eta = 0.018$ for the NRAO telescope, and $\eta = 0.0045$ for the telescope at Woodbury. An important quantity for our analysis will be the dynamic range between the initial candidate detection level η_1 and the subsequent reobservation threshold η_T . For our observations, $\eta_1/\eta_T \sim 10^3$. For reference, $\eta_1/\eta_T \sim 2$ for the original META reobservations.

4. Interstellar Scintillation

In this section we first summarize key results from CLS97. We then use the formalism developed by CLS97 to show that our new observations exclude the META candidates from being intrinsically steady ETI transmitters.

Table 1. META Followup Observational Log

Right Ascension (J2000)	Declination	Epoch	η_1
1420 MHz candidates			
03 06 46.87	+58 02 19.4	1997 December 17 1998 February 5 1998 April 28	224
19 34 29.27	+47 31 19.7	1997 December 19 1998 April 28	35.6
21 59 20.33	+38 33 40.5	1997 December 11 1998 April 28	33.6
23 43 38.89	+08 33 02.2	1997 December 11 1998 April 28	33.0
2840 MHz candidates			
08 00 33.13	−08 31 54.4	... ^a	747
08 57 31.47	−15 47 36.7	... ^a	75.4
14 18 22.30	+57 26 44.9	1998 March 23	31.8
14 39 26.08	+46 26 55.3	1998 March 23	31.8
18 22 51.59	−19 29 38.0	1998 March 23	52.8
18 40 52.38	−23 14 20.9	1998 March 23	44.4
20 02 17.13	+30 47 04.1	1998 March 23	33.2

^aThis candidate was not reobserved as part of this work.

Note. — η_1 is the initial detection strength of the candidate during the META, in units of the mean META noise level.

Compact radio sources observed at centimeter wavelengths (e.g., pulsars) scintillate. Sufficiently distant radio sources ($\gtrsim 0.5$ kpc) are in the saturated scintillation regime.¹ The signal from an intrinsically steady source of flux density S will have an observed flux density of gS (in the absence of noise). The probability density function of the ISS gain g is $p(g) = e^{-g}U(g)$, where $U(g)$ is the Heaviside step function. A point discussed at length in Cordes & Lazio (1991) and CLS97 is the ancipital nature of this probability density function: Scintillations can act to render an otherwise undetectable signal detectable, but because the most probable gain is $g = 0$, ISS will more likely render undetectable an otherwise detectable signal.

A key result of CLS97 was the role of noise in META. They showed that the META candidates could be explained as rare combinations of a gain $g > 1$ *and* a noise spike. The ISS gain has a decorrelation time scale of minutes to days, depending upon a source’s Galactic longitude and latitude and the velocities of the source, intervening medium, and observer. The noise in the spectrometer decorrelated on the time scales required to compute a fast Fourier transform ($\simeq 20$ s). The failure of the immediate reobservations to detect the source could be understood as due to a reobservation threshold that was too high coupled with the noise decorrelating; later reobservations had the additional complication that the ISS gain had also decorrelated either partially or fully.

CLS97 quantified the probability of redetecting a source with the conditional probability $P_{2d}(I_T|I_1; S, \rho)$ (CLS97, Appendix B). Here a source of intrinsic strength S is detected initially at a level I_1 . At a later time, for which the ISS gain correlation coefficient is ρ (with $0 \leq \rho \leq 1$), the source is then reobserved with a reobservation detection threshold of I_T . Following CLS97 the quantities can be normalized by the noise level at the time of initial detection, $P_{2d}(\eta_T|\eta_1; \zeta, \rho)$, where $\zeta \equiv S/\langle N \rangle$. However, the expression given by CLS97 (their equation [B19]) is incomplete. The correct formulation of $P_{2d}(I_T|I_1; S, \rho)$ is

$$P_{2d}(I_T|I_1; S, \rho) = \frac{\int_{I_T}^{\infty} \int_{I_1}^{\infty} dI'_2 dI'_1 f_{2I}(I'_1, I'_2; S, \rho)}{P_{d,\text{scint}}(I_1; S)}. \quad (1)$$

The joint intensity probability density function is $f_{2\eta}(\eta_1, \eta_2; \zeta, \rho)$ and is given by equation (B13) of CLS97. The signal detection probability of a scintillating source, above a threshold η_1 , is $P_{d,\text{scint}}(\eta_1, \zeta)$ and is given by equation (B10) of CLS97.

For completeness Figure 1 shows the corrected $P_{2d}(\eta_T|\eta_1; \zeta, \rho)$ for the values of η_T and η_1 relevant to the META observations and with various values of ζ . Figure 1 reproduces one of the panels of Figure 3 in CLS97, but with the corrected expression for $P_{2d}(\eta_T|\eta_1; \zeta, \rho)$, equation (1). Comparison of Figure 1 and Figure 3 in CLS97 shows that the figures in CLS97 that display $P_{2d}(\eta_T|\eta_1; \zeta, \rho)$ are qualitatively correct and largely quantitatively correct.

¹We emphasize that like CLS97 we assume that saturated scintillations, in which the rms intensity modulation is 100%, apply. This is unlikely to be the case for the rest of Project Phoenix observations, as most of its observations target nearby stars, so the distance to any potential transmitters is not sufficient for the saturated scintillation regime to obtain. More distant sources in the beam may be in the saturated scintillation regime, though.

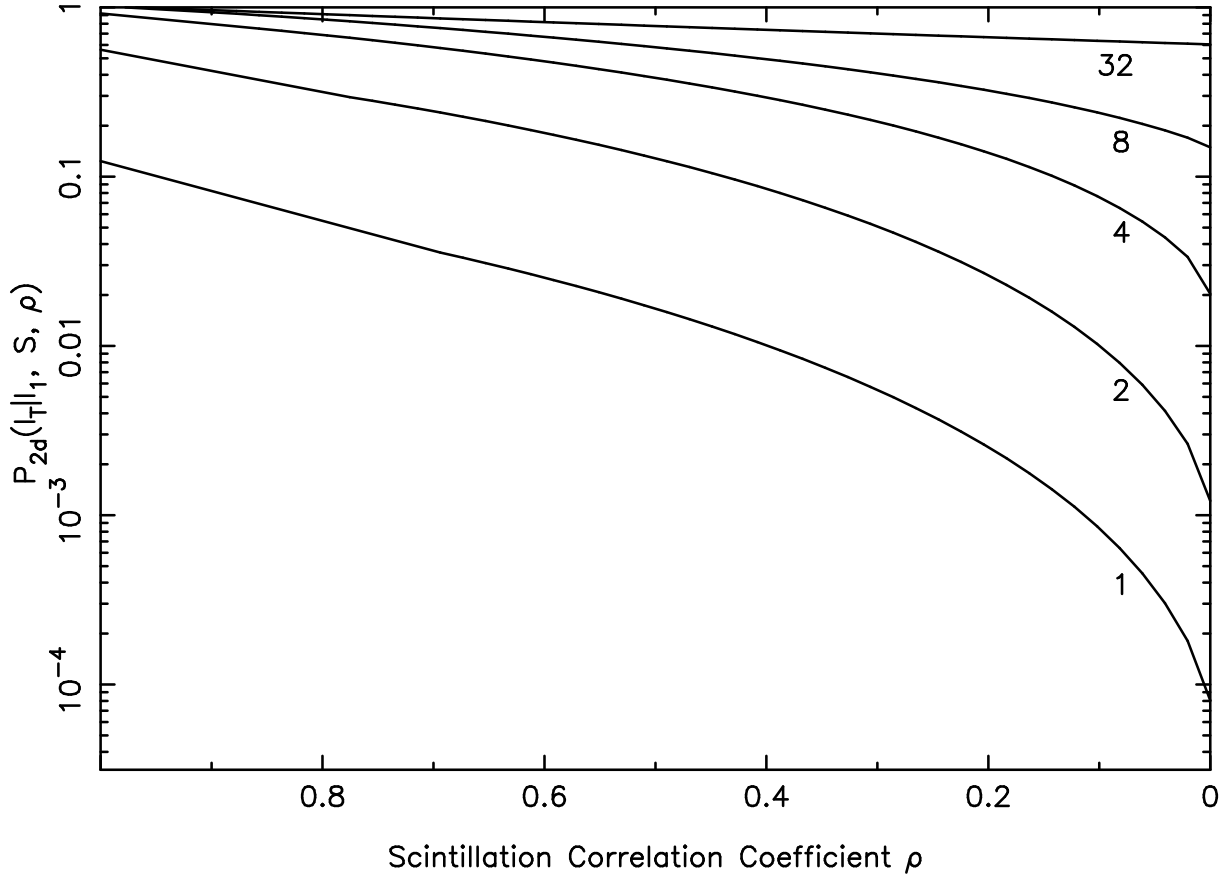


Fig. 1.— The second detection probability $P_{2d}(\eta_T|\eta_1;\zeta,\rho)$, using the corrected expression of equation (1), for values of the initial detection threshold, $\eta_1 \approx 32$, and redetection threshold, $\eta_1 \approx 20$, relevant to the META observations. The curves are labeled by the value of the intrinsic signal strength ζ . This figure should be compared to Figure 3 of CLS97.

Scintillations impact our observations in two ways. First, the original motivation in conducting the observations was to use detection thresholds low enough to rule out the scintillation hypothesis for the META candidates. Second, however, our use of the two telescopes means that a scintillating signal could be undetected in the reobservations with the telescope at Woodbury.

We consider first our coincidence detection scheme, because if this scheme is not robust against scintillations, we can draw no conclusions about the comparisons with the META observations. In the coincidence detection scheme the initial observation threshold is that of the NRAO telescope, $\eta'_1 = 0.018$, and the reobservation threshold is that of the telescope at Woodbury, $\eta'_T = 0.0045$. The degree of correlation of the scintillations is unknown, but we consider two possibilities to illustrate the possible range of second detection probabilities.

In the case $\rho = 1$, there exists no analytic expression for $P_{2d}(\eta_T|\eta_1; \zeta, \rho = 1)$, but we can develop a useful approximation. The bivariate intensity density function is

$$f_{2\eta}(\eta_1, \eta_2; \zeta, \rho = 1) = \frac{1}{1+2\zeta} I_0 \left(\frac{\zeta \sqrt{\eta_1 \eta_2}}{1+2\zeta} \right) \exp \left[-\frac{(\eta_1 + \eta_2)(1+\zeta)}{1+2\zeta} \right], \quad (2)$$

where $I_0(x)$ is the first order modified Bessel function. We rewrite $P_{2d}(\eta_T|\eta_1; \zeta, \rho = 1)$ as

$$P_{2d}(\eta_T|\eta_1; \zeta, \rho = 1) = \frac{1 - \int_0^{\eta_T} d\eta_2 \int_0^{\eta_1} d\eta_1 f_{2\eta}(\eta_1, \eta_2; \zeta, \rho = 1)}{P_{d,\text{scint}}(\eta_1; \zeta)} \quad (3)$$

and then, because $\eta'_T, \eta'_1 \ll 1$, we expand in powers of η'_T and η'_1 . We find

$$P_{2d}(\eta_T|\eta_1; \zeta, \rho = 1) \approx \left\{ 1 - \frac{\eta_T \eta_1}{1+2\zeta} \left[1 - \frac{(1+\zeta)(\eta_T + \eta_1)}{2(1+2\zeta)} + \frac{\zeta^2 \eta_T \eta_1}{(1+2\zeta)^2} \right] \right\} e^{\eta/(1+\zeta)}. \quad (4)$$

In order to explain the META candidates as scintillating sources, CLS97 also found that $\zeta \sim 3$. For all reasonable values of $\zeta > 0$, the redetection probability for the Project Phoenix coincidence detection procedure is $P_{2d}^{(P)}(\eta'_T|\eta'_1; \zeta, \rho = 1) > 0.999$.

If the scintillations are uncorrelated completely, $\rho = 0$, then P_{2d} can be evaluated analytically.

$$P_{2d}(\eta_T|\eta_1; \zeta, \rho = 0) = P_{d,\text{scint}}(\eta_T; \zeta) = e^{-\eta_T/(1+\zeta)} \quad (5)$$

For a source of strength comparable to that preferred by CLS97, $P_{2d}^{(P)}(\eta'_T|\eta'_1; \zeta, \rho = 0) \simeq 0.999$. A strict *lower* limit to the detection probability is obtained by setting $\zeta = 0$ (implying that no source is present!) for which $P_{2d}^{(P)} \geq 0.996$.

Thus, the coincidence detection scheme is at least 99.6% robust in detecting actual scintillating sources of the source strength estimated by CLS97. Unfortunately, we can place no reasonable limits on ρ . In order for $\rho \ll 1$, the spatial scale length of the scintillations would have to be comparable to or smaller than the baseline between NRAO and Woodbury, $b \approx 500$ km. At 1.4 GHz ($\lambda = 21$ cm), such a scintillation scale length is equivalent to a scattering angle $\theta_d \sim \lambda/b \sim 0''.09$. While large, a scattering angle of this magnitude is not unprecedented. Various low Galactic latitude sources

have scattering diameters comparable to or larger than this value (e.g., NGC 6334B, Moran et al. 1990; Cyg X-3, Molnar et al. 1995). As the META candidates have low Galactic latitudes as well, we can place no constraints on ρ .

In the roughly 10 yr between the META observations and the observations we report (§3), scintillations would have decorrelated completely. In this case the expression for P_{2d} is given in equation (5). For the META reobservations, the reobservation threshold is that of the NRAO telescope, $\eta_T = 0.018$. Thus, $P_{2d}^{(M)}(\eta_T|\eta_1; \zeta \sim 3, \rho = 0) = 0.996$ for a source strength comparable to that estimated by CLS97, and the lower limit is $P_{2d}^{(M)}(\eta_T|\eta_1; \zeta = 0, \rho = 0) = 0.982$.

In order to find the overall probability of detection, we multiply the detection probability from the coincidence scheme with the redetection probability to the original META observations, $P_{2d} = P_{2d}^{(P)} P_{2d}^{(M)}$. The strict lower limit to the overall redetection probability ($\zeta = 0$) is 97.8%, while it is in excess of 99.5% for a source strength comparable to that estimated by CLS97.

These confidence levels are calculated using the nominal META sensitivity. The actual sensitivity varied from $2.3 \times 10^{-25} \text{ W m}^{-2}$ to $4.3 \times 10^{-24} \text{ W m}^{-2}$. HS93 do not report the appropriate value for each candidate. Using the highest sensitivity reduces the overall redetection probability to $P_{2d}(\zeta \sim 3) \geq 98.6\%$ while using the lowest sensitivity increases the overall redetection probability to $P_{2d}(\zeta \sim 3) \geq 99.9\%$.

CLS97 also show the number of (uncorrelated) reobservations required to exclude completely the possibility that the META candidates were actual ETI transmitters. In the case that $\eta_T \rightarrow 0$, the number of reobservations required is 10. Because the maximum number of reobservations for any one candidate is only 3 (at our sensitivity level), we cannot apply this second reality criterion.

5. Gravitational Microlensing

As a second extrinsic cause of signal modulation, we consider gravitational microlensing. In this scenario, the continuous transmissions of an ETI transmitter are amplified briefly by a foreground object passing close to the line of sight of the transmitter. This scenario was not covered by CLS97. Gravitational microlensing has an apparent advantage over ISS in that the amplification gain for microlensing A is $A \geq 1$. Bennett & Rhie (1996), Alcock et al. (1996), and Di Stefano (1999) consider the more general problem of detecting terrestrial planets via gravitational lensing.

Gravitational microlensing has been detected in optical monitoring programs of stars toward the Galactic bulge, the Magellanic Clouds, and M 31 (e.g., Udalski et al. 1994; Alcock et al. 1995; Ansari et al. 1996). Because gravitational effects are achromatic, we can make use of the formalism developed to describe these monitoring programs. We shall assume that neither source size nor source blending are important as both can contribute to apparent chromatic effects (Han, Park, & Jeong 2000).

Given the observed signal strengths of the META candidates and the reobservation thresholds

in our new observations, the microlensing amplifications required are $A \gtrsim 100$, somewhat smaller than the ratio η_1/η_T . Although we have not conducted extensive tests, a la CLS97, an important conclusion of CLS97 continues to hold: The noise in the META spectrometer would have played a key role in the initial detections, if these are otherwise constant signals. The decorrelation time scale of the noise, approximately 20 s, was a crucial feature of the signal model developed by CLS97. This short decorrelation time explained how the immediate reobservations conducted during META were unable to detect the signal. Like ISS, the decorrelation time of gravitational microlensing, $\Delta t_{\text{gl}} > 2$ hr (Paczynski 1986), is much longer than the time it took for the immediate reobservations to occur. Thus, gravitational microlensing need not account for the full dynamic range η_1/η_T . Amplifications this large have been termed extreme gravitational lensing events (EGLEs) or extreme magnification events (EMEs) (Paczynski 1995; Wang & Turner 1996; Gould 1997).

Paczynski (1986) determined the probability for the gravitational microlensing amplification to exceed a fiducial value A_0 , $P_{\text{gl}}(A > A_0)$. For $A_0 \gg 1$ this function can be approximated as $P_{\text{gl}}(A > A_0) \simeq \tau A_0^{-2}$, where τ is the optical depth to microlensing. The exact values for τ depend upon the details of the population of lensing objects. Existing estimates for the microlensing optical depth toward the inner Galaxy are sufficient though to place severe constraints on the META candidates. The optical depth toward the inner Galaxy is $\tau \sim 10^{-6}$ (Kiraga & Paczynski 1994; Udalski et al. 1994; Alcock et al. 1995). This estimate depends upon such factors as the mass function and Galactic distribution of the lenses (Gyuk 1999). In particular, the value can be lower by factors of several, depending upon the Galactic coordinates of the line of sight. For the purposes of this analysis, we ignore these differences. Including these effects would make our conclusions more robust.

In order to explain the META candidates, we require $A_0 \sim 100$ so that $P_{\text{gl}}(A > A_0) \sim 10^{-10}$ toward the inner Galaxy. On average, we expect that in order to obtain an amplification as large as A_0 , the number of *background* objects, i.e., ETI transmitters, must be $NP_{\text{gl}} \sim 1$. The relevant quantity here is the number of background objects as the number of lenses has already been incorporated through the factor of τ in P_{gl} .

We therefore require $N \gtrsim 10^{10}$ in order to explain the META candidates as being real signals modulated by gravitational microlensing. HS93 estimate that if all of the META candidates represent real signals, the Galactic population of such transmitters is only roughly 2×10^6 . The observed number of candidates is insufficient, by orders of magnitude, to allow them to be explained as gravitational microlensed transmitters.

We can extend this analysis to future surveys as well. Suppose that we consider lower amplification values. The number of transmitters required within the inner Galaxy must still be $N \sim \tau^{-1} \sim 10^6$ for gravitational microlensing to be an important factor. This estimate for the gravitational lensing optical depth is for background sources located in the Galactic bulge. We assume that these sources are located within a Galactocentric radius $R = 1$ kpc. Then the sur-

face density of such transmitters must be $0.3 \text{ pc}^{-2} (R/1 \text{ kpc})^{-2}$, assuming a disk-like distribution of transmitters. We have assumed a disk-like distribution of transmitters based on the apparent concentration of META candidates to the Galactic plane. Extending this distribution into the Galactic disk, the average distance between the ETI transmitters would be roughly $0.6 \text{ pc} (R/1 \text{ kpc})$. Given that programs such as the SETI Institute’s Project Phoenix have not detected any transmissions from nearby stars, this surface density is far higher than the actual surface density. We conclude that gravitational microlensing is unlikely to play an important role in modulating the signals from ETI transmitters within the Galaxy, unless there are populations of disk and inner Galaxy ETI transmitters whose densities differ significantly.

6. Conclusions

We have reported additional, more sensitive observations of nine of the eleven extrastatistical candidates from the Megachannel Extraterrestrial Assay (Table 1). We have used these observations to evaluate the most simple hypothesis amenable to testing (CLS97): That the extrastatistical candidates were intrinsically steady sources, either extraterrestrial transmitters or an as-yet unknown population of narrowband natural sources, whose intensities were amplified by propagation effects, either interstellar scintillations (§4) or gravitational microlensing (§5).

Using the formalism developed in CLS97 (with a correction for the second detection probability, equation 1), we have shown that these more sensitive limits exclude the scintillation hypothesis: The META candidates do not in general represent a population of scintillating sources. This hypothesis can be excluded at a confidence level of at least 97.8% (for the case of an intrinsically weak source) to a level in excess of 99% (if the source strengths are comparable to that favored by CLS97). Because two of the META candidates were not reobserved with this sensitivity, we cannot rule out the possibility that one or both of them represent ETI transmitters.

We have also shown that the number of transmitters in the inner Galaxy would have to approach 10^{10} if gravitational microlensing is to be invoked to account for the META candidates. Current constraints on the number of transmitters in the Galaxy are orders of magnitude smaller than this number. Furthermore, existing surveys already suggest that the Galactic population of ETI transmitters is sufficiently small so that gravitational microlensing is unlikely to play a role in future surveys.

HS93 derived various limits on various populations of transmitters. These limits can be revisited in light of our results (see Figure 10 of HS93): There is no more than 1 Kardashev Type II civilization that has constructed an isotropic beacon near the H I line or its second harmonic within the Galaxy or nearest 10^3 galaxies. There are no more than 10^4 Kardashev Type I civilizations broadcasting isotropically within the Galaxy and no more than 1 such civilization with a directed beacon transmitter having 30 dB or more gain anywhere within the Galaxy. More stringent limits on weaker transmissions will have to await future surveys.

We thank J. Cordes for helpful discussions, Jaem for assistance with equation (2), and the referee for suggestions that improved the presentation of our results.

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